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EXPANSION FORCE AS A BOHMIAN QUANTUM EFFECT TO TEST HUBBLE CONTROVERSY AND EARLY DARK ENERGY

Jacques Fleuret
Telecom ParisTech
33 rue des Roses
92160 Antony, France
jacques.fleuret@telecom-paristech.org

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Abstract

An additional expansion force was proposed ten years ago to explain flat rotation curves without requiring dark matter. This force has been applied to various astronomical or cosmological situations. More recently, it has been shown that it could result from Bohmian Quantum mechanics, bridging the gap between it and cosmology and leading to a universe evolution different from that of the Standard Model. In particular, the expansion rate was found to depend on the observation distance, which could shed new light on the Hubble controversy. In this article, this point is studied in the context of a very simple model of a homogeneous universe that would be either finite or infinite, and with a view to providing a precise test of the H measurements. It is also shown that the universal expansion force has decreased over time, as assumed by the "early dark energy" hypothesis. Will the effect of this force allow us to resolve the controversy? In any case, the results of this new approach can allow us to test the validity of the theory itself as well as the finitude or infinity of the universe.

Keywords: Bohmian Quantum Mechanics; expansion; Hubble Constant; infinite Universe ; finite Universe ; early dark energy.

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1 Introduction

Despite the capabilities of the Standard Model, our current understanding of the Universe faces two major challenges: the lack of proof of the existence of Dark Matter and the fact that the value of the Hubble Constant depends on the experimental measurement methods [1 to 5].

The expansion force theory [6] defines an additional force to Newtonian attraction, without modifying it, unlike MOND theory [7].

Considered as the expression of a new principle of dynamics, this force has been applied to the study of various astrophysical situations, including the study of an expanding inhomogeneous universe [8 to 10], the hypothesis of a mass erosion phenomenon [11], the application to the planar structures of dwarf galaxies [12], studies leading to the idea that gravity would be dual, with a well-known attractive part and a repulsive part (the expansion force at the origin of the expansion of the universe, which would require the presence of negative matter [8, 10]).

Moreover, it has been shown that this force would result from a quantum phenomenon, within the framework of Bohmian Quantum Mechanics, during the interaction of two elementary particles associated with their pilot waves [13]. The radial part of this force do generate the expansion of the universe and its lateral part explains the observed excess rotational speeds [14].

This quantum approach, applied to the dynamics of a distant galaxy (and its associated pilot wave) interacting with all the masses of the universe, has made it possible to construct a model of the universe evolution that differs from the Standard Model: a universe assumed to be flat, homogeneous, and infinite, which, moreover, has neither beginning nor end. In this framework, the expansion rate has been shown to depend on the observation distance or (equivalently) on the time corresponding to this distance.

We do examine here in more detail the variation laws of the expansion rate, with a view to provide an element of response to the Hubble controversy, depending on whether the universe—assumed to be very simple: flat and homogeneous—appears to be "finite" or "infinite".

After a review of the generation of this model, we will examine more closely these two cases.

2 Review of the expansion force as a Bohmian Quantum effect

To model the attraction of a distant galaxy by all the masses of the universe using Bohmian Quantum Mechanics [13], a pilot wave (assumed to be Gaussian) was associated with this galaxy, considered as a "particle" subject to the potential generated by all the masses of the universe. For a homogeneous universe of density ρ_0, we thus obtained the following dynamical equation, for the position r of this "particle":

$$\frac{dr}{dt} = \frac{rt}{t^2+\tau^2} - \frac{MG}{r^2}t \tag{1}$$

$$\text{with } M(r) = \frac{4}{3}\pi\rho_0 r^3 \tag{2}$$

and the time parameter τ given by:

$$\tau = \frac{2m\text{Д}^2}{\hbar} \tag{3}$$

Д being the width of the pilot wave (supposed to have a gaussian shape).

The time parameter τ being extremely large, eq (1) was easily approximated as:

$$\frac{dr}{dt} = -Krt \tag{4}$$

where

$$K = \frac{4}{3}\pi G\rho_0 \tag{5}$$

We note here that it is the Newtonian term which prevails in eq. (1).

Furthermore, it was verified that this approach is equivalent to the introduction of an expansion force complementary to Newton's attraction, since the following relationship can be deduced from equations (2), (4), and (5):

$$\ddot{r} = -\frac{MG}{r^2} + \frac{\dot{r}^2}{r} \tag{6}$$

The solution to eq. (4) then led to the following universe dynamics:

$$r = Re^{-K\frac{t^2}{2}} \tag{7}$$

Independently of considerations related to the evolution of the universe - detailed in [14] - this approach notably concludes with the following evolution of the expansion rate:

$$H = \frac{\dot{r}}{r} = -Kt \tag{8}$$

[Present time t_0 has been denoted negatively, because we live in an epoch of expansion, later followed by an epoch of contraction of the universe]

3 "Finite" or "infinite" universe?

The important point to consider here is that it is the Newtonian term that governs the dynamics of the universe: the particle is attracted by all masses of the universe, and everything happens as if these (internal) masses were gathered at the center of the sphere in question (at the observer's level).

However, it should be noted that Gauss's theorem is only valid outside this sphere.

If, conversely, we were to consider a (simplistic) universe that was perfectly homogeneous and infinite, any particle located anywhere in this universe would obviously see all Newtonian contributions cancel out in opposite pairs. It is therefore clear that the above analysis does not apply to a homogeneous infinite universe, but rather to a homogeneous finite universe.

In a homogeneous infinite universe, there can therefore be no Newtonian term, and the following dynamical equation must apply:

$$\frac{dr}{dt} = \frac{rt}{t^2+\tau^2} \tag{9}$$

In reality, the degree of cancellation of the Newton's force will depend on many aspects (local or global, degree of homogeneity, curvature, etc.). This is why quotation marks are used to evoke "finite" or "infinite" universes.

In both cases, our center of interest is the expansion rate variation.

4 Case of a "finite" universe

In this case, the results of the previous study [13] apply, with the universe dynamics given by equation (7) and the linear variation of H:

$$H = \frac{\dot{r}}{r} = -Kt \tag{8}$$

which are illustrated in Figures 1 and 2.

The expansion is also characterized by the acceleration coefficient:

$$q = \frac{r\ddot{r}}{\dot{r}^2} \tag{10}$$

which is estimated to have the value ½ at the present time t_0. This implies:

$$H_0 = -\frac{2}{t_0} = \sqrt{2K} \tag{11}$$

Differentiation as a function of t around t_0 (or of r around r_0 via eq. (7)) highlights which variations of the Hubbel Constant should currently be observed at first degree:

$$\frac{dH}{H_0} = \frac{dt}{t_0} = \frac{dr}{2r_0 L\left(r_0/R\right)} \tag{12}$$

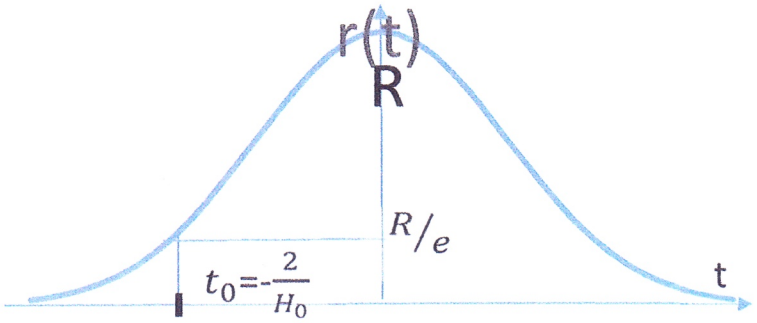

Fig. 1: Dynamics of a "finite" universe (Eq. (7))

We see that this model differs from the standard model: there is no Big Bang, and the expansion phase will be followed by a contraction phase.

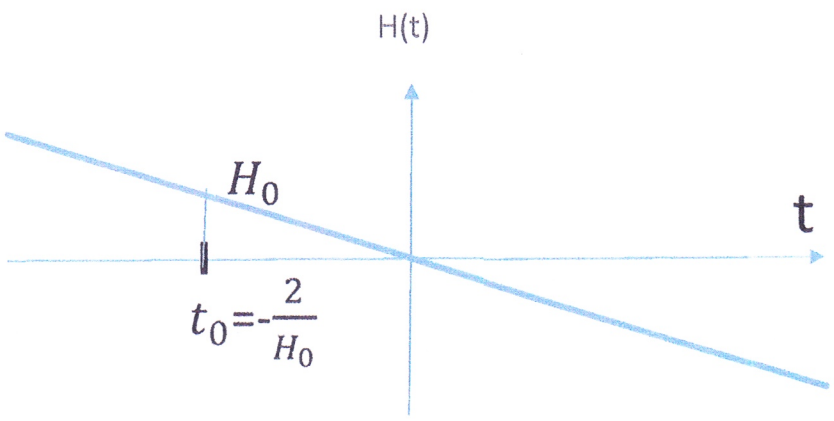

Fig. 2: Evolution of the expansion rate for a "finite" universe (Eq (8))

Recall that the present time is negative: we are on the expansive part of the universe evolution; more precisely, before the inflection point of the curve r(t) on the left, which represents the currently accelerated expansion. We see that H is a decreasing function of r or t. In other words, this model predicts that the measurement of H should decrease with the observation distance, as is indeed the case with the present measurement results, which are weaker for the CMB [4,5].

5 Case of an "infinite" universe

In this case, equation (9) leads to the following dynamics:

$$r = c\sqrt{t^2 + \tau^2} \tag{13}$$

where c is the speed of light (note that the speed $\dot{r}$ is always less than c and tends towards c for an infinite time).

The expansion rate then varies according to:

$$H = \frac{t}{t^2+\tau^2} = \frac{c}{r^2}\sqrt{r^2 - c^2\tau^2} \tag{14}$$

And the calculations of differential increases around (r_0, t_0) lead to:

$$\frac{dH}{dt} = H_0^2\left(\frac{\tau^2}{{t_0}^2} - 1\right) = \frac{c^2}{{r_0}^2} - 2H_0^2 \tag{15}$$

$$\frac{dH}{dr} = \frac{1}{r_0}\left(\frac{1}{t_0} - 2H_0\right) = \frac{c}{r_0^3}\frac{\left(2c^2\tau^2 - {r_0}^2\right)}{\sqrt{{r_0}^2 - c^2\tau^2}} \tag{16}$$

The variations of r and H are illustrated in figures 3 and 4.

The dynamics of an infinite universe therefore includes a contraction phase followed by an expansion phase. It also does not include a Big Bang (at most a minimal shrinkage at time 0). In this sense, our proposals fall under the theories of universes without beginning or end [15 to 17].

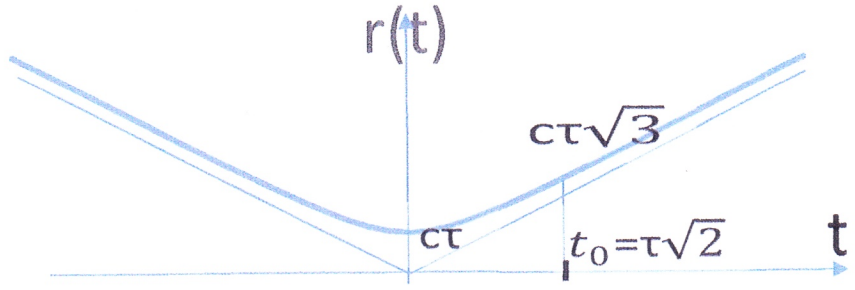

Fig. 3: Dynamics of an "infinite" universe (Eq. (13))

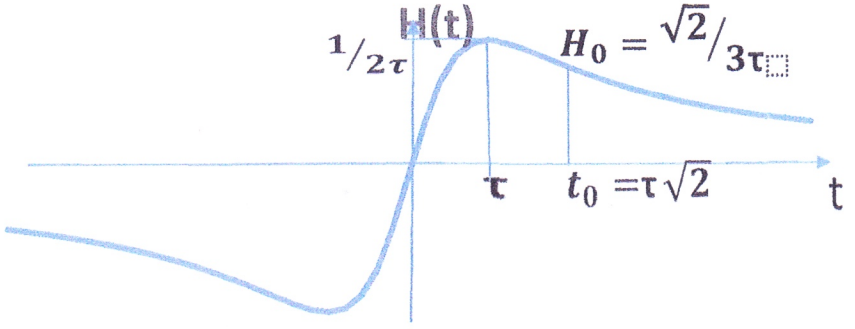

Fig. 4: Evolution of the expansion rate for an "infinite" universe (Eq (14))

The expansive part of curve (13) means that we are at a positive time t_0 and the current acceleration coefficient, of value ½, implies here the relationship between t_0 and τ:

$$t_0 = \tau\sqrt{2} \tag{17}$$

with $$H_0 = \frac{\sqrt{2}}{3\tau} = \frac{2}{3t_0} \tag{18}$$

We are therefore located after the maximum of H and we see that H is still a decreasing function of r and t.

6 Universal expansion force

It should be noted that, unlike equation (7) specifying the expansion force for a "finite" universe, the calculation of $\ddot{r}$ for an "infinite" universe leads to:

$$\ddot{r} = \frac{\tau^2}{t^2}\frac{\dot{r}^2}{r} \tag{19}$$

In this case, the expansion force to be considered undergoes an additional temporal variation.

This result seems to call into question our initial intuition [6] of an expansion force equal to $\frac{\dot{r}^2}{r}$, which explains flat rotation curves.

In reality, the difference between our two idealizations lies in the fact that the second ("infinite" universe) assumes conditions such that Newton's force can be neglected by large-scale symmetry: this obviously depends on the considered entire environment and, in particular, on the conditions of homogeneity, curvature, and topology.

It is clear that at the level of the motion of stars in a galaxy, Newton's force must be considered, justifying our expansion force in $\frac{\dot{r}^2}{r}$. On the other hand, at the level of the expansion of the universe that interests us here, we can imagine that the conditions of homogeneity, curvature, and topology agree so that our simplifying assumptions called "infinite universe" do apply, therefore leading to eq. (19), which can be called the "universal expansion force":

$$\ddot{r} = \frac{\tau^2}{t^2}\frac{\dot{r}^2}{r} = \frac{c\tau^2}{(t^2+\tau^2)^{3/2}} \qquad (19)$$

7 Expansion force versus early dark energy

Let's examine the variation over time of this universal expansion force.

We see that it decreases over the expansive period, being in fact inversely proportional to the volume of the universe r^3. For $t_0 = \tau\sqrt{2}$, it would today be about 5 times weaker than for t=0.

This result seems to be in good agreement with the recent hypothesis called the "early dark energy field" proposed by Riess and Kamionkowski [18 to 20] according to which "the baby universe was expanding faster than we think" and "an additional repulsive force that was pushing against space at the time and has since died out."

According to my theory, this force has not totally died out. It has been caused by a Bohmian Quantum effect, its energy would come from a continuous erosion process, and it should be considered as a dual aspect of gravity, whose effect gradually diminishes with the expansion of the universe.

After ten years of rejection, these ideas perhaps deserve attention.

8 Conclusion

The present theory does indeed predict an evolution of the expansion rate as a function of the observation distance (or corresponding time). Formulas (8) and (12) theoretically govern the predicted evolutions in both cases of a "finite" or "infinite" universe, as do formulas (14) and (15, 16) for the differential versions. These developments are therefore likely to provide concrete tests for the estimates of H in the context of the Hubble controversy.

We also observe that the theory of the "infinite" universe establishes a relationship between H and τ, that is, a bridge between long-distance cosmology and quantum mechanics. Since τ depends on the spatial extensions of galaxies (Д), it is conceivable that these extensions evolve with expansion and time. The

precise variation law will obviously result from a more complete modeling of a more real universe (with curvature and inhomogeneities).

If there were to be a concordance between the experimental data from H measurements and the propositions in this article, this would have the merit of providing an attempt to resolve the Hubble controversy, as well as an element of validation of the expansion force theory. Furthermore, we have shown that the expansion force varies with time and that, for an "infinite" universe, it would be about 5 times smaller than at the beginning of the expansion. This result suggests that it could be linked to the recent idea of the "early dark energy field", or even support it more generally [18 to 20]

As for the issue of a finite or infinite universe, the debate obviously remains open. As mentioned above, the terms "finite" or "infinite" (written in quotation marks) are based on whether or not Newton's force is taken into account, as it can be "cancelled" by symmetry. Incidentally, intermediate situations can be envisioned, in which the effect of this force would be more or less reduced, depending on the actual conditions of the universe's unfolding and its real characteristics: local or global homogeneity defects, partial curvatures, etc. The corresponding models could provide as many more refined derivations of the contribution to the expansion force.

As here formulated, the present propositions presuppose an absence of curvature and the underlying assumption of a very simple internal topology, which tends to conflate the concepts of finiteness and the fact that the universe has no boundary. In particular, since measurements of the CMB [4,5] have revealed a non-zero, but weak, curvature, our approach can be considered from this point of view as a first approximation.

Much modeling work will still be necessary to bring our simple idealization closer to a more real universe, and perhaps definitively resolve the Hubble controversy as well as the question of Dark Matter.

Isn't the real Universe much richer than our approximations claim [21]?

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